Utah Geological Survey

Project: September 12, 2002, fire-related debris flows east of Santaquin and Spring Lake, Utah County, Utah			Requesting Agency: Santaquin City
By: Greg N. McDonald Richard E. Giraud	Date: 11-20-02	County: Utah	Job No: 02-09
USGS Quadrangle: Payson Lakes (965) Spanish Fork (1006) Springville (966) West Mountain (1007)		Section/Township/Range: Sections 31 and 32, T. 9 S., R. 2 E.; Sections 6 and 7, T. 10 S., R. 2 E.	

INTRODUCTION AND PURPOSE

On the evening of September 12, 2002, intense rainfall triggered fire-related debris flows in multiple drainages on Dry Mountain east of Santaquin and Spring Lake at the south end of Utah Valley (figure 1). Major debris flows originated in tributaries 2, 3, 4, 5, and 6 (as defined by the U.S. Forest Service [2001]), and deposited debris on alluvial fans west of Dry Mountain (figure 1). Farther south, smaller flows from tributaries 7, 9, 11, 12, and 14 were reported (U.S. Forest Service, 2002) but not evaluated as part of this investigation. Debris and floodwater from tributaries 2, 3, and 4 flowed into developed areas causing property damage in two subdivisions. Floodwater from tributary 5 entered a subdivision but caused no reported damage. Prior to the event, Dry Mountain was determined to have a heightened debris-flow and flooding hazard due to the Mollie wildfire that burned much of the west side of the mountain during the summer of 2001.

At the request of Roger Carter, Santaquin City Manager, we performed this investigation to describe and document the debris flows. The scope of work for this investigation included review of aerial photos, published geologic reports and maps, and post-fire assessment letters and reports; field mapping of debris-flow deposits; and a field traverse of the drainage basin of tributary 4. Our investigation included evaluation of volume, runout distance, and deposit area. We visited the area on September 13, 2002, as part of the Utah State Division of Emergency Services Interagency Technical Team (IAT), and performed additional field work on September 17, 24, and October 9, 2002.

CONCLUSIONS AND RECOMMENDATIONS

Based on this geologic investigation of the September 12, 2002, fire-related debris flows east of Santaquin and Spring Lake, the Utah Geological Survey (UGS) concludes the following:

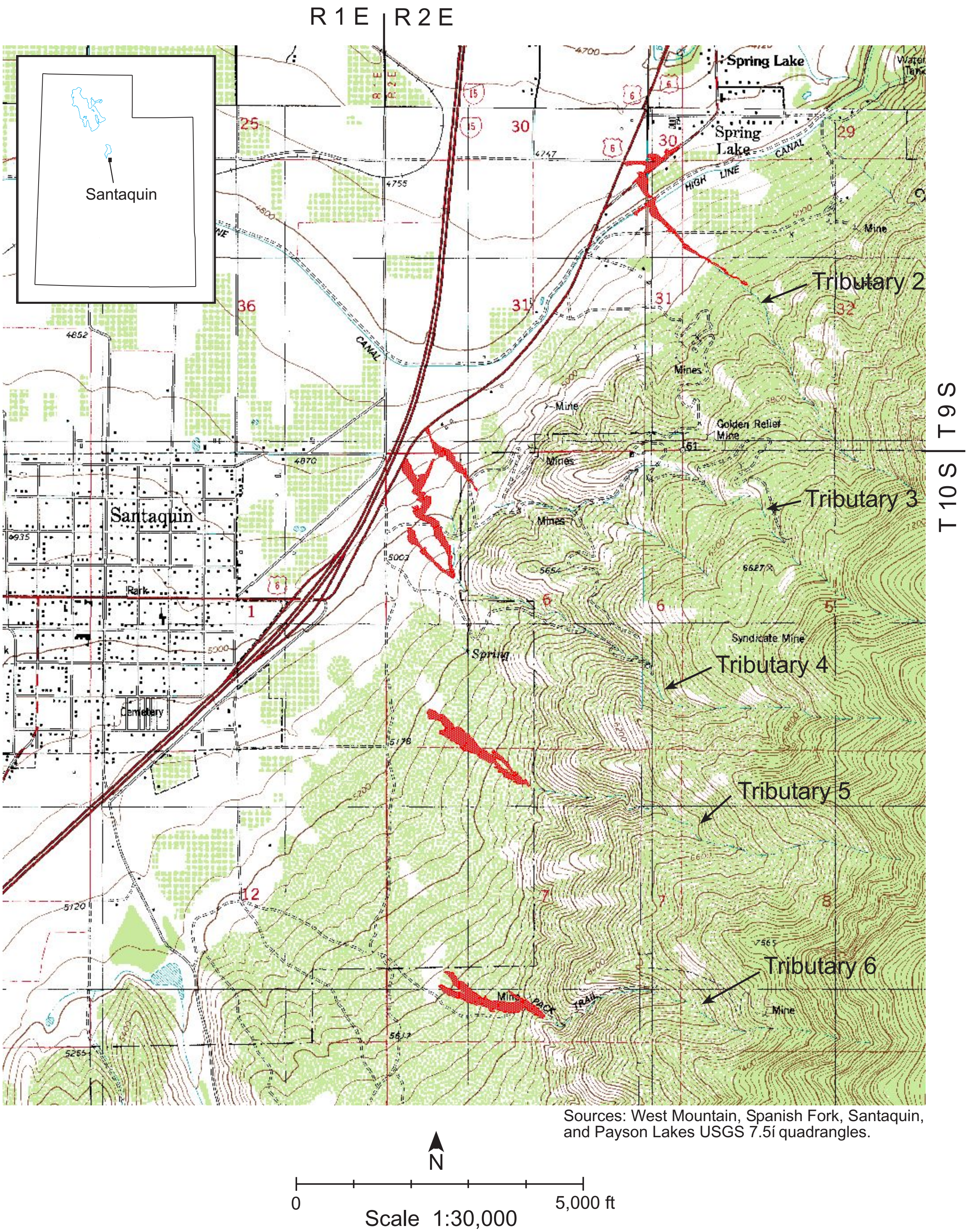

Figure 1. Approximate extent of September 12, 2002, debris-flow deposits and alluvial-fan flooding (red).

- The debris flows were triggered by intense thunderstorm precipitation on the upper burned slopes of Dry Mountain, which eroded soil by sheetwash and rilling. Runoff rapidly concentrated into channels, eroding and bulking sediment to a debris-flow sediment-water concentration. The flows continued to grow by accumulating channel sediment until they reached the canyon mouths where they spread out and deposited debris on alluvial fans.

- Water-repellent soils and diminished vegetation in the tributaries caused by the Mollie fire contributed to the debris flows of September 12, 2002. Because it takes several years for soil and vegetation in burned watersheds to recover to pre-burn conditions, the short-term debris-flow hazard will be heightened for several years.

- Field reconnaissance of the tributary 4 drainage basin indicates ample sediment remains for future debris flows. Given the similarities of tributary 4 to the other drainages, they likely also have ample sediment for future debris flows.

Regarding the continuing debris-flow hazard east of Santaquin and Spring Lake, the UGS recommends:

- The guidelines and recommendations outlined in Pietramali (2002), Solomon (2001), Rasely (2001), and U.S. Forest Service (2001, 2002) BAER reports to manage the debris-flow hazard should be followed.

- A debris-flow hazard existed before the fire and will remain after the drainage basin vegetation recovers to pre-burn conditions. Therefore, measures will also need to be taken to reduce the long-term non-fire-related debris-flow hazard.

- Future development will likely encroach farther onto the alluvial fans, exposing more property to hazards. Evaluation of the hazards and implementation of hazard-reduction measures are more easily accomplished prior to development and should therefore be considered now as part of the long-term planning of east Santaquin and Spring Lake.

- Designs to reduce hazards should include evaluation of the drainage basins for potential debris-flow-volume yields and consider the long-term maintenance of any structures.

During our investigation, we also recognized the potential for other geologic hazards, including rock fall and surface fault rupture, and recommend all hazards be addressed as part of long-term planning for development east of Santaquin and Spring Lake.

BACKGROUND

Physical Setting and Geology

Santaquin City is at the southern end of Utah Valley at an elevation of about 5,000 feet. The community of Spring Lake is about 2 miles northeast of Santaquin at an elevation of about 4,800 feet (figure 1). East of Santaquin and Spring Lake, a section of the Wasatch Range called Dry Mountain rises to elevations of over 9,800 feet. Drainages involved in the September 12, 2002, fire-related debris flows (tributaries 2 through 6) drain the west side of Dry Mountain and rise in elevation from about 5,200 to 5,600 feet at their mouths to about 8,200 to 9,000 feet. Tributary 4 is roughly 9,500 feet in length and channel gradient ranges from about 16 percent (9 degrees) near its mouth to nearly 43 percent (24 degrees) in its upper reaches; the average gradient is about 29 percent (16 degrees).

Dry Mountain is composed of generally north-striking, east-dipping, Precambrian quartzite, sandstone, siltstone, schist, gneiss, and amphibolite that have been locally intruded by pegmatite and granite dikes, overlain by Mississippian limestone and shale (Demars, 1956; Witkind and Weiss, 1991). Dry Mountain contains local Quaternary deposits of alluvium, colluvium, talus, and mass-movement deposits. Quaternary deposits west of Dry Mountain include sediments of Pleistocene Lake Bonneville, and colluvium and alluvial-fan deposits ranging in age from pre-Lake Bonneville to modern (Machette, 1992; Harty and others, 1997). The Nephi segment of the Wasatch fault zone is exposed east of Santaquin as prominent escarpments along the base of Dry Mountain. Figure 2 shows the debris flows on the alluvial fans at the fault-bounded mountain front.

Mollie Wildfire and Post-Fire Hazard Assessment

The September 12, 2002, debris flows partly resulted from a wildfire that burned much of Dry Mountain during late summer 2001. The Mollie fire was a human-caused event that burned over 8,000 acres of U.S. Forest Service, State of Utah, and private land primarily on the west side of Dry Mountain between August 18 and September 1, 2001 (U.S. Forest Service, 2001). Nearly half of the burned area, including most of the higher elevations, has soils with high to very high erosion potential (U.S. Forest Service, 2001). The Mollie fire is described in detail in the Burned-Area Emergency Rehabilitation (BAER) report (U.S. Forest Service, 2001).

Post-fire assessments of the burn area included, in addition to the BAER report, debris-flow and flood-hazard assessments by the UGS (Solomon, 2001) and the U.S. Natural Resources Conservation Service (NRCS) (Rasely, 2001). All of the assessments recognized a heightened debris-flow/flooding hazard for the tributaries on the west side of Dry Mountain. The BAER report recommended emergency treatments and a warning system be implemented. The UGS noted "…heightened debris-flow and flood hazards exist at subdivisions in Santaquin east of Interstate-15 as a result of the fire, particularly at the mouths of tributaries 3 and 4…" and "A heightened flood hazard exists along the east side of subdivisions directly west of tributary 5…" The NRCS concluded "Santaquin is in a high risk condition for intense flooding, avalanches, and destructive debris yielding events…for the next few years…" and proposed flood routing and

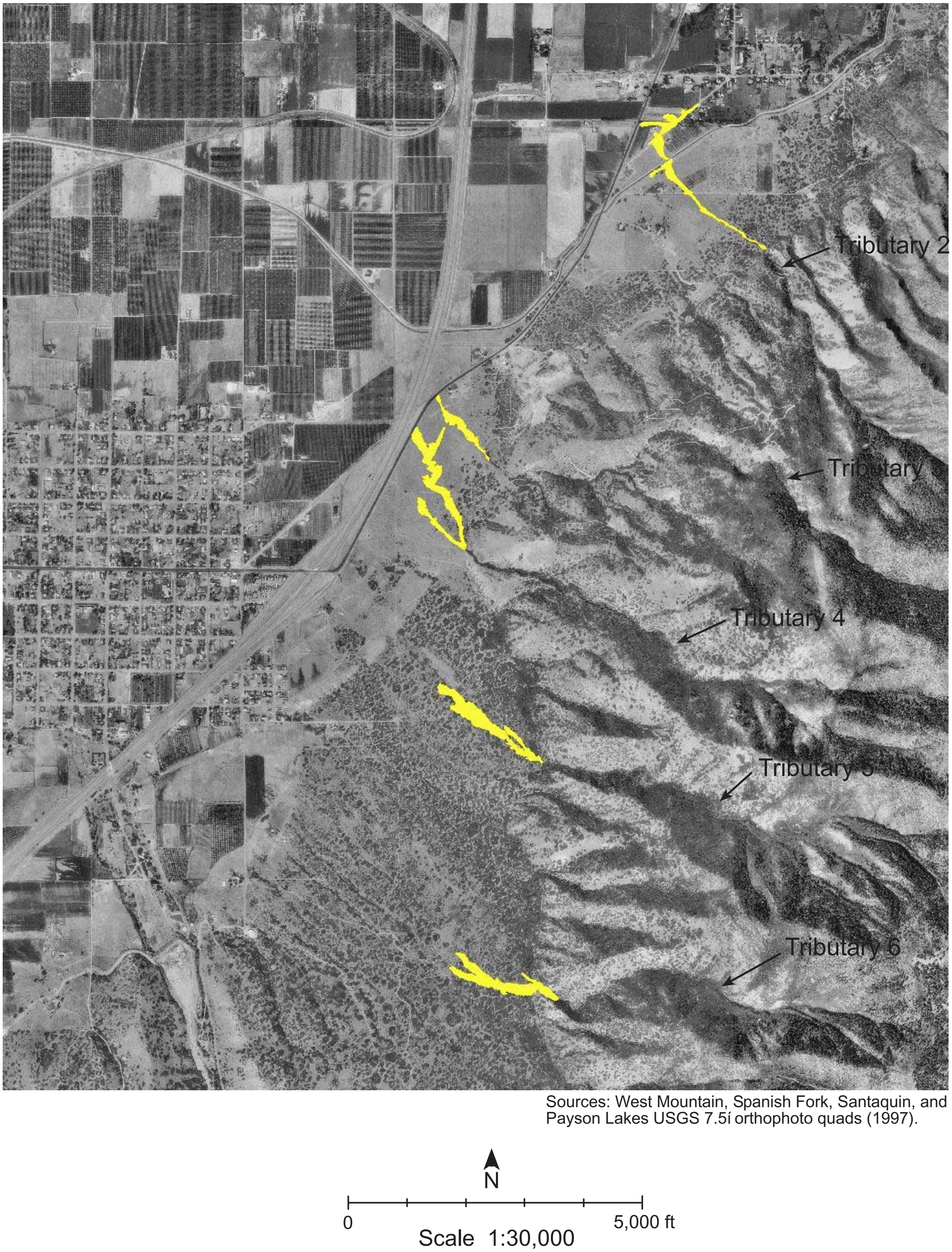

Figure 2. Orthophoto map showing debris-flow deposits (yellow).

“debris trapping treatments” to reduce the hazard. Some efforts were made to reduce the debris-flow and flooding hazards. However, the September 12, 2002, debris flows showed the need for more comprehensive risk-reduction measures.

SEPTEMBER 12, 2002, DEBRIS FLOWS

Debris-Flow Initiation and Sediment Bulking

The debris flows from Dry Mountain were triggered by intense thunderstorms on the evening of September 12, 2002. Specifically, the initiating event was a convective thunderstorm imbedded within stratiform cloud precipitation (Brian McInerney, Hydrologist, National Weather Service, verbal communication, October 1, 2002). Scattered rain showers had occurred earlier in the day. Rain-gage data collected in 1-hour intervals at a weather station near the ridgeline above tributary 4 (National Weather Service Forecast Office, 2002) showed elevated precipitation levels between the hours of 4:30 and 7:30 p.m. (figure 3). Homeowners in the neighborhood below tributary 4 indicated the debris flow entered the subdivision around 6:40 p.m. The precipitation measured between 4:30 and 7:30 p.m. apparently triggered the debris flows and subsequent flooding. Even though the weather station only records data hourly, the triggering rainfall likely fell as intense short-duration precipitation. Total rainfall recorded for September 12, 2002, was 0.55 inches.

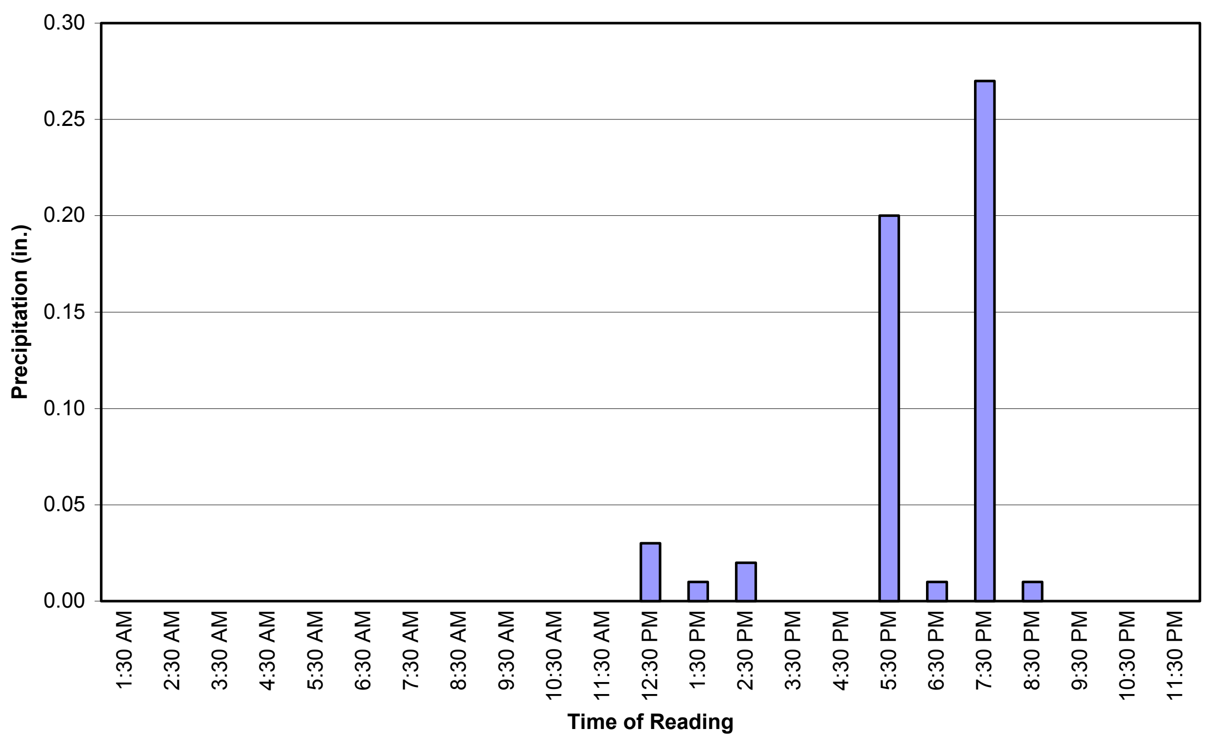

Figure 3. September 12, 2002, hourly rain-gage data. (Data source: National Weather Service Forecast Office, 2002)

We traversed up tributary 4 on September 17, 2002, to assess debris-flow initiation processes and sediment bulking characteristics. Hillslopes in the upper reaches of the basin showed evidence indicating the debris flow began as intense runoff and sheetwash erosion concentrated as rills and in local drainages. Whereas areas burned in the Mollie fire had begun to revegetate, some of the soils still exhibit water-repellent conditions. The debris flow began entraining sediment in the upper portion of the drainage basin and continued to bulk sediment, progressively downstream, through erosion and scour of the main channel. We observed no evidence of significant sheetwash or hillslope erosion in the lower portion of the drainage. We observed minor debris-flow deposition in the main channel in the drainage basin, mostly along sections of the middle and lower reaches, as levees, mud coatings, and overbank deposits. Most of the debris-flow volume was deposited on the alluvial fan at the mouth of tributary 4. The other four debris flows likely originated in a similar manner, as opposed to initiation caused by shallow landsliding. Initiation processes observed in tributary 4 are similar to those that have been documented by Meyer and Wells (1997) and Cannon (2001) at other fire-related events.

Debris-Flow Deposits

The UGS performed field reconnaissance of the debris-flow deposits that included mapping their extent and estimating flow thickness to derive volumes, and observations of physical characteristics including the effects of post-debris-flow flooding. The debris flows were deposited as narrow linear lobes on alluvial fans at the base of Dry Mountain (figures 1, 2, and 4a). Most of the debris flows were a viscous mixture of sediment and water in the upper fan area that exhibited more dilute behavior downfan. Narrow, linear, paired levees formed that flanked the viscous debris flows on the alluvial-fan apices. The levees confined flows and channeled sediment farther downfan, increasing the runout distance. The levees have sharp lateral margins and steep flanks and are up to 3 feet thick (figure 4b). The main lobes that were deposited farther downfan exhibited features related to higher water contents. These main lobes were generally less than 2 feet thick and had margins less steep than the levees. All deposits had a consistency similar to wet concrete when saturated and exhibit high dry strength.

Soil types in the debris-flow deposits are highly variable, ranging from clayey gravel near the mountain front to clayey sand in distal deposits downfan. We observed clasts up to about 3 feet in diameter in the upper parts of the deposits near the mountain front, where exposures indicated deposits are matrix-supported. All of the debris flows were followed by a period of muddy stream flooding that washed fine-grained sediments from portions of the deposits, leaving a clean, gravel and cobble lag in the channel and redepositing the fines downfan. Data for the deposits are summarized in table 1. Deposit areas and volumes were calculated using GPS survey data and thickness estimates. Brief descriptions of each deposit are presented below.

(a) View looking west of tributary 4 north deposit in Santaquin subdivision.
Photo by Dale Deiter, U.S. Forest Service.

(b) Levee deposits of tributary 4 north lobe on the fan apex.

Figure 4. Debris-flow deposits.

(c) Toe of tributary 5 overbank deposit north of main lobe.

(d) View of tributary 6 deposit looking downfan (eastward).

Figure 4. (continued)

Table 1. Summary of debris-flow deposit area, volume, and runout.

Flow	Deposit Area (square yards; acres)	Deposit Volume (cubic yards; acre ft.)	Runout Distance (feet)
Tributary 2	33,700; 7.0	5,500; 3.4	3,000
Tributary 3	12,800; 2.6	2,200; 1.4	1,400
Tributary 4	46,000; 9.5	20,000; 12.4	2,300 (N. lobe), 1,300 (S.lobe)
Tributary 5	41,500; 8.6	13,000; 8.1	2,200
Tributary 6	21,800; 4.5	10,000; 6.2	1,200

Tributary 2

The debris flow from tributary 2 remained channeled from the mouth of the drainage for about 1,600 feet before spreading out and depositing much of its sediment. Debris from the flow blocked a section of the High Line Canal. Below the canal, the debris flow and canal water flooded property and houses in a Spring Lake subdivision.

Tributary 3

The deposit from tributary 3 was the smallest of the five. Part of the deposit filled a subdivision storm-water detention basin. Below the basin, part of the flow ran through an equipment yard causing minor damage. No houses were impacted by the tributary 3 debris flow.

Tributary 4

The debris flow from tributary 4 was the most damaging of the five. When the flow reached the mouth of tributary 4, it split into two lobes. The larger, north lobe flowed through the Santaquin subdivision causing substantial property damage (figure 4a, figure 5). Most of the north lobe did not follow city streets but established a direct path down the alluvial fan. Subsequent floodwater traveled down roadways. The south lobe flowed down an undeveloped portion of the fan and deposited debris on a newly excavated subdivision road south of the existing development.

Tributary 5

The debris flow from tributary 5 deposited sediment at the mouth of the drainage east of developed areas. Post debris-flow floodwater reached a subdivision, including a newly excavated road; however, no major property damage was reported. The debris-flow deposit on the upper portion of the fan contained considerable woody debris and trees up to several inches in diameter (figure 4c). Near the top of the deposit a moderate-sized lobe is present north of the main flow that contains much less woody debris and large clasts, and likely represents a later surge.

Tributary 6

The tributary 6 deposit was similar in character to the tributary 5 deposit. Neither the debris flow nor associated floodwater affected any developed areas (figure 4d).

(a) Debris-flow sediment deposited at the intersection of Lambert Avenue and Apple View Street. The debris flow rafted vehicles and filled basements with sediment.

(b) The debris-flow impact broke through this basement window of a house on Apple View Street.

Figure 5. Debris-flow/flooding damage in Santaquin subdivision.

(c) Debris-flow damage to garage doors of house on Peach Street.

(d) Debris-flow damage to the back wall of house on Peach Street.

Figure 5. (continued)

Debris-Flow Impacts and Damages

Three of the five debris flows and associated flooding caused damage to infrastructure, property, and houses in the communities of Santaquin and Spring Lake. Most of the damage occurred at the Santaquin subdivision from the north lobe of the tributary 4 debris flow. Vehicles were moved (figure 5a), some were pushed into houses; basements were flooded and filled with debris as ground-level windows were broken (figure 5b); house and garage doors were buckled inward (figure 5c); and the back wall of one house was broken by impact forces (figure 5d). A preliminary report prepared by Ryan Pietramali of the Utah Division of Emergency Services indicates five homes and two businesses received major damage and 27 homes received minor damage at a total cost of about $500,000 (U.S. Small Business Administration Damage Assessment Report dated September 19, 2002).

SUMMARY

The September 12, 2002, debris flows east of Santaquin and Spring Lake were related to the 2001 Mollie fire and triggered by intense precipitation on the upper slopes of Dry Mountain. Because it takes several years for soil and vegetation in burned watersheds to recover to pre-burn conditions, and ample sediment remains in the basins, the short-term debris-flow hazard will be heightened for several years. In addition, a debris-flow hazard existed before the fire and will remain after the drainage basin vegetation recovers to pre-burn conditions.

To reduce the hazard, the guidelines and recommendations outlined in Pietramali (2002), Solomon (2001), Rasely (2001), and U.S. Forest Service (2001, 2002) BAER reports should be followed. Any measures taken to reduce the short-term risk of fire-related debris flows should not preclude the need for risk reduction from long-term non-fire-related debris flows. As development encroaches farther onto the alluvial fans, hazard evaluation and reduction measures should be considered as part of long-term planning and development in east Santaquin and Spring Lake. In addition to debris flows, other geologic hazards, including rock fall and surface fault rupture, exist east of Santaquin and Spring Lake and should also be addressed in planning for development in the area.

DISCLAIMER

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